MINISTRY OF AGRICULTURE, EGYPT.

TECHNICAL AND SCIENTIFIC SERVICE.

Bulletin No. 15.

THE RUSTS AND SMUTS

OF

WHEAT, BARLEY, AND OATS,

BY

H. R. BRITON-JONES, A.R.C.S., D.I.C., etc.

MYCOLOGIST TO THE MINISTRY OF AGRICULTURE.

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EXPLANATION OF PLATES AND FIGURES.

Plate I.—Rusts of Wheat: (1) Yellow Rust (*Puccinia glumarum*); (2) Black Rust (*Puccinia graminis*); (3) Orange Rust (*Puccinia triticina*).

Plate II.—Black Rust (*Puccinia graminis*): (1) Part of uredosorus; (2) Germinating uredospore; (3) Part of teleutosorus; (4) Germinating teleutospore. Yellow Rust (*Puccinia glumarum*): (5) Uredospore; (6) Germinating teleutospore. Orange Rust (*Puccinia triticina*: (7) Part of uredosorus in section; (8) Teleutosorus in section. (1 to 6 after Eriksson, 7 and 8 after Butler).

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THE RUST AND SMUTS OF WHEAT, BARLEY, AND OATS.

THE RUSTS OF WHEAT.

Introduction.—There are three distinct forms of rust which attack wheat in Egypt. In English-speaking countries these are commonly called Black Rust, Yellow or Golden Rust, and Orange Rust. In Egypt, the name of *Sada* is given to all three. The Black Rust is caused by *Puccinia graminis* (Pers.), Yellow Rust by *Puccinia glumarum* (Eriks and Henn.), and Orange Rust by *Puccinia triticina* (Eriks). Black rust alone is said to cause in India an annual loss of one million pounds sterling. In America, the three rusts cause a loss of eight million pounds sterling, and it seems certain that the annual loss due to rusts on the world's cereals is not less than a hundred million pounds sterling. So far, no estimate has been made of the damage caused by these serious diseases in Egypt. Records show, however, that there has been a vast increase in damage during the past ten years. More will be said about this later.

The Black Rust (*Puccinia graminis*).

The commencement of the attack usually occurs on the leaf sheath or at the base of the leaf blade. The fungus produces chocolate-brown pustules ranging from 0·5 millimetre to 0·5 centimetre in length (Plate I Fig. 2). At first, these pustules (uredosori) are covered by the skin (epidermis) of the plant. Soon, however, the epidermis becomes ruptured, exposing a chocolate-brown powder which consists of hundreds of tiny bodies (uredospores) (Plate II, Fig. 1). On microscopic examination, each uredospore will be found to be oval in shape, with a yellowish centre surrounded by a colourless area, and the whole enclosed in a colourless wall. The spore is one-celled, and is covered with tiny spines, the use of which is for holding on to the surface on which it falls. It measures about $\frac{1}{500}$ by $\frac{1}{350}$ centimetre. The uredospores are blown about by the wind, and in the presence of moisture germinate in a few hours.

On germination, they produce a delicate thread (germ tube) (Plate II, Fig. 2) which emerges at a thinned area of the cell wall called the germ pore. When germination takes place on the surface of the wheat plant, the germ tube produces, over one of the breathing pores (stoma) of the plant, a swelling called the appressorium. From the appressorium, another fine thread enters through the stomatal opening and eventually gives rise to a system of threads (mycelium) whose growth is not indefinite but limited in extent. The mycelium grows between the cells of the plant tissue and obtains its food by sending in finger-like suckers (haustoria) into the cells. From this mycelium, several short erect stalks arise, and these produce at their apices a uredospore. The uredospores increase in size and finally rupture the epidermis of the plant. On thus becoming exposed to the air, they are blown about by the wind and carry on infection as before. In some cases, these spores are produced in such numbers as to colour the ground. Such was the case at Gîza this year.

The production of the uredosori goes on until the latter part of April, when the uredospores, instead of producing the chocolate-brown uredosori, produce pustules which are quite black in colour. This is another stage in the life-history of the fungus, and is known as the teleuto-stage. The black pustules are the teleutosori, and the teleutospores differ from the uredospores in being dark brown, two-celled, thick walled, and with no spines, and they measure about $\frac{1}{200}$ by $\frac{1}{500}$ centimetre. The walls of the apical cells are very much thickened at the tips (Plate II, Fig. 3). The teleutospores are not capable of immediate germination, but require a period of rest of several months. On germination, each cell of the teleutospore produces a thread which is composed of four cells (promycelium). Each cell of the promycelium gives rise to a very fine thread (sterigma) which bears a single colourless spore (sporidium) at its apex (Plate II, Fig. 4). The sporidia become detached from the sterigmata very easily, and are blown about by the wind. It has been definitely proved that these sporidia cannot infect the wheat plant, but in other countries they infect the leaves of barberry (*Berberis vulgaris* L.), on which they produce two other kinds of spores called aecidiospores and spermatia. The spermatia are functionless, but the aecidospores are able to infect wheat and to produce uredosori. Only the uredo- and teleuto-stages have been found in Egypt, and there seems to be no doubt but that the fungus is able to dispense everywhere with the stage which occurs on the barberry.

The Yellow Rust (*Puccinia glumarum*).

The first appearance of the disease is usually seen on the upper surfaces of the leaves of the upper half of the plant. The fungus

produces orange-yellow pustules which are arranged end to end and in rows, but each separate from the other. At first they form long narrow stripes on the leaves (Plate I, Fig. 1), but later the whole surface of the leaf may become covered with the pustules. These pustules (uredosori) are much narrower and shorter than those of black rust. They are at first covered by the epidermis of the leaf, which later becomes ruptured, exposing the orange-yellow or golden powder (uredospores) (Plate II, Fig. 5). The uredospores are small, bright orange, spherical to subspherical bodies which measure $\frac{1}{500}$ by $\frac{1}{300}$ centimetre in diameter. They are entirely filled with orange colouring matter, and their walls are covered with tiny spines. They are blown about by the wind on to the neighbouring wheat plants and produce more uredosori in the same manner as black rust.

Later in the season (the end of March in Lower Egypt), the uredosori are replaced by black teleutosori. The teleutospores have not such thick walls as those of black rust. They are dark brown and two-celled, measuring about $\frac{1}{700}$ by $\frac{1}{200}$ centimetre, and are arranged in groups which are often separated by a number of sterile, club-shaped structures called paraphyses. Like those of the black rust the teleutospores require a period of rest before germination, and then they produce sporidia in the same manner (Plate II, Fig. 6). The sporidia cannot infect wheat. No further stage in the life history is known, but possibly there was formerly an aecidial stage which has been lost.

The Orange Rust (*Puccinia Triticina*).

This rust first appears as small, oval, bright orange pustules on the lower surfaces of the lower leaves. The pustules are wider and shorter than those of yellow rust, and they are irregularly scattered over the surfaces of the leaves. Later, they spread upwards on the plant and appear on both sides of the middle and upper leaves, but mostly on the upper surfaces (Plate I, Fig. 3). Unlike black rust, the pustules very rarely run into one another. These pustules (uredosori) (Plate II, Fig. 7) have not been observed on any part of the wheat plant in Egypt except the leaves, although thorough search has been made.

The uredospores of orange rust are the same size and shape as those of the yellow rust, but groups of yellow rust spores are more consistently round than those of orange rust. The chief differences between the uredospores of the orange and yellow rusts when examined in water under a microscope are :—

(1) The colouring matter of the spores of orange rust does not completely fill the cell, but there is a definite colourless area between the brown-orange centre and the cell wall.

(2) The cell wall is also brownish and not colourless as in yellow rust.

Like those of both yellow and black rusts, they are covered with tiny spines.

The next stage of the fungus (teleuto-stage) (Plate II, Fig. 8) appears about the last week in March in Lower Egypt, and can only be distinguished from the teleuto-stage of yellow rust by the fact that the teleutosori are irregularly distributed over the leaf surfaces, and not in rows. The teleutospores are also like those of the yellow rust in size and structure. The sporidia, produced on germination, cannot produce infection, and no other stage of the life history is known.

General Consideration.

Black rust attacks all parts of the plant above ground, but yellow rust occurs mostly on the leaves and between the husk and grain; the latter also attacks the leaf sheaths and stems, but to a far lesser degree than black rust.

Orange rust is confined to wheat.

In Egypt black rust occurs on barley (*Hordeum vulgare* L.), oats (*Avena sativa* L.), wild oats (*Avena fatua* L.), and also on two wild grasses (*Lolium perenne* L. and *Hordeum murinum* L.).

Yellow rust also occurs on barley.

There may be other plants attacked by these parasites which have not yet been found. Plants thus attacked are called host plants.

Although the forms of the rusts on wheat are morphologically similar to the forms on the other hosts, the parasites have become so highly specialized on each of its hosts that they are unable to infect the others. These forms, therefore, must differ physiologically, and, in consequence, have been split up into what are termed " biological species." In America it has been found that the black rust of wheat cannot infect oats directly, but can do so if passed through barley. No experiments have been carried out in Egypt to determine whether the forms on wheat can infect the other hosts, but it has been observed that barley and oat crops growing side by side with badly rusted wheat crops are often fairly free from rust, and that the part of the barley or oat crop nearest to the wheat is not more rusted than the rest of the crop. This indicates that the forms on wheat cannot infect barley or oats. Experiments will, however, be carried out to determine whether the black rust on wheat can infect barley and oats, and whether the yellow rust can infect barley. It is possible, indeed highly probable, that the behaviour of the fungi in Egypt is different from that in other countries. Possibly this can be explained by the

fact that the forms are undergoing evolution in all parts of the world, and that it is taking a different course in different countries.

The question which naturally arises in connection with these three rusts is, how do they exist from one season to another in order to bring about fresh infection every year. Many attempts have been made to explain this, but so far no satisfactory answer can be given.

Eriksson tried to explain this by putting forward the theory that the fungus lives in such close combination with the grain that, even under very high-power microscopes, the cell contents (protoplasm) of the grain cannot be distinguished from the protoplasm of the fungus. When the seed is sown and germinated, the fungus element is said to be carried through the plant body in close combination (symbiosis) with the protoplasm of the plant, and when suitable conditions arise the fungus protoplasm develops and becomes differentiated into threads (hyphæ) which produce uredosori. This theory, however, has been independently disproved by several workers. The method adopted was by growing susceptible wheats in spore-proof cages and obtaining rust free plants. Thus the source of infection must be external and not internal in the plant. The view that is most favoured at the present time is that the uredospores are able to live in the soil from one season to another, and thus bring about infection every year. In India, however, attempts have been made to preserve uredospores during the hot weather, but without success.

Klebhan, working in Germany, exposed plates to the air at different times of the year and found that several thousands of uredospores, and spores of other fungi, fell from the air on to the plates. He believes that millions of spores are blown into the air in every grain-growing country, and in consequence they have become universally distributed. Similar experiments have also been carried out by workers in America, who have confirmed his observations.

A third explanation advanced is that the fungus is able to live on accidental wheat plants or wild grasses.

Whichever of these views is the correct one the question still remains to be answered why it is that the pustules do not appear on wheat until the end of February. It has often been observed that the period of incubation is considerably longer in cold weather than in warmer weather. Apart from temperature, the humidity of the air is an important factor in deciding the date of appearance of rust. Without moisture the uredospores cannot germinate, and, even if moisture is present, a suitable temperature is also necessary to produce uredosori. Further, with increase of temperature and water content of the soil, there is an increase in the turgidity of the cells and rate of transpiration of the wheat. These facilitate the entrance of the fungus into the plant. Thus it would seem that, although the fungus may

*

have gained entrance into the plant, external conditions of temperature and moisture must be such as to effect the internal metabolism of the plant so as to make it suitable for the fungus to complete its development and to produce uredosori. This also explains why it is that wheat and barley, germinated at Gîza in mid-April, became rusted when only a few inches above the ground.

Observations on Different Varieties of Wheats.

The accompanying chart (Plate IV) is a record of some careful observations carried out this year on Plot C at the experimental farm at Gîza. A plan of the plot is also given (Plate III).

Orange Rust.—It will be seen from the columns giving the degrees of susceptibility of the various wheats to the three rusts that the Indian, Australian, South African, and Tunisian wheats are more susceptible to orange rust than the Egyptian. Considering next the date of appearance of this rust on these susceptibele wheats, the uniformity of the date of appearance is very striking. It appeared on all of them about the ninety-eighth day after sowing. The rust appeared later on the Egyptian wheats and at different times.

Yellow Rust.—The Egyptian wheats are decidedly more susceptible to yellow rust than any of the others. The date of appearance of the rust was, with one exception, on the hundred and eighth day after sowing. It appeared on the other kinds of wheat at different times.

Black Rust.—Black rust principally attacks the Indian wheats, and in every case its appearance was either on or within a day or two of the hundred and first day after sowing.

From the above it seems reasonable to draw the conclusion that, apart from the effect of temperature and moisture, the date of appearance of a specific rust is largely dependent on the susceptibility of the plant to that rust. The exceptions, for instance the early appearance of orange rust on Sunset and Florence, can be explained by the fact that, being very early ripening varieties, they are much more affected by a slight rise in temperature than the later ripening varieties. Thus, in the case of Sunset and Florence, temperature was the predominant factor.

These observations will be repeated each season until the conditions arrive which will be favourable to black rust. It is common knowledge that, taking the country in general, the Indian wheats, although known to be highly susceptible to black rust, were almost

clean this year. Such observations will be necessary in order to obtain a true estimate of the degree of susceptibility of the various wheats. The figures denoting susceptibility for this year will then be compared with those of the coming years and the highest figure for each rust taken as a true estimate of the susceptibility of the wheat concerned.

Historical.

Records show that there has been a gradual increase of rust attack in the country during the last ten years. W. Lawrence Balls stated that rust does practically no damage to cereals here owing to the fact that the local wheats are naturally immune. ("Text Book of Egyptian Agriculture," Vol. II, 1910, p. 686). The following are extracts from the Egyptian Agricultural Notes, "Wheat Rust," 1911 :—

"(1) The name 'Rust' is applied to several different kinds of parasitic fungi attacking wheat and barley, but only one kind has as yet appeared commonly in Egypt upon the wheat crop. This, however, is of such common occurrence that it may be found in every wheat field in early summer. In most cases the attack is so slight that it is inconspicuously affected, but it may become so severe that it is ruined.

"(2) The pustules appearing upon the leaves, stem, or even the ears of wheat, in Egypt, consist mainly of spores, each of which is spherical and yellow."

The above paragraphs show clearly that the common rust in Egypt at that time was the yellow rust, since orange rust does not attack the ears and stems, and black rust has oval and not round spores.

Of late years *Hindi* (Indian) wheats have been extensively grown in Egypt, in addition to the *Baladi* (native) wheats, and records for 1915 to 1920 show that :—

In 1915, *Hindi* were badly attacked and *Baladi* fairly clean.*
In 1916, *Baladi* ,, ,, ,, *Hindi* ,, ,,
In 1917, *Hindi* ,, ,, ,, *Baladi* ,, ,,
In 1918, *Baladi* ,, ,, ,, *Hindi* ,, ,,
In 1919, *Hindi* ,, ,, ,, *Baladi* ,, ,,
In 1920, *Baladi* ,, ,, ,, *Hindi* ,, ,,

During a tour of inspection throughout Egypt this year all the crops of *Baladi* wheats were observed to be badly attacked by yellow

* It is probable that these records are correct concerning the attacks on *Hindi*, but that the attacks on *Baladi* were the same for all the years, or that the increase which possibly occurred in 1915, 1917, and 1919 was overlooked owing to the contrast between the two types of wheats in these years.

rust and with little or no orange or black rust. The *Hindi* wheats (with the exception of those at Gîza, and two other crops which will be referred to below) were free from yellow rust and with very little black or orange rust. When there was any doubt as to whether a certain wheat plant was *Baladi* or *Hindi*, the rust was a sure index, for it was tested on several occasions and invariably proved absolutely reliable in identifying the type of wheat. It seems certain, therefore, that the rust which attacked *Hindi* so badly in 1915, 1917, and 1919 was black rust, and that it was yellow rust that was responsible for the attacks on *Baladi* in 1916 and 1918. The latter was certainly the cause of the attack in 1920. Although this regular alternation of the attacks of black rust on Indian wheat and yellow rust on *Baladi* cannot as yet be explained, it is of very great importance in connection with the control of rusts in Egypt. It is too early to predict a serious attack of black rust on *Hindi* wheat next year, but if it should turn out to be so, then the very obvious thing to do the following year (1922) will be to sow *Hindi* wheats throughout the country, since it will then be *Baladi*'s turn to be attacked by yellow rust. In addition to direct observations being carried out on the crops of this next year, the following experiment will be carried out to try and predict the type of wheat which is going to be badly attacked. Small plots of both *Baladi* and *Hindi* wheats will be sown early in the season, so that they will become rusted before the main crops are sown. The results on these experimental plots will then be compared with the attacks later on the main crops and, if identical, the same procedure will be carried out each year, thus enabling the cultivators to be informed which type of seed to sow.

Control Measures.

Although it is hoped that the regular alternation of attacks will continue, the only reliable method of controlling rusts on wheat is by breeding immune varieties. It has already been stated that the *Baladi* wheats are to a large extent immune to black and orange rusts, and that the Indian, Australian, and South African wheats are largely immune to yellow rust. The degrees of susceptibility of each wheat studied were noted for each rust separately: it is not sufficient to have a variety of wheat which is resistant to only one species of rust. These are already plentiful in Egypt. To be of true economic value the wheat produced must be resistant to the most serious rusts in Egypt, namely, yellow and black rusts. It must not be supposed, however, that a wheat which is resistant to rust in Lower Egypt will necessarily prove resistant when grown in Upper Egypt. The balance is very delicate, and with change in climate and cultural methods it

is very liable to be upset, and for a wheat immune in one region to become susceptible in another, as has been observed in other countries from time to time. Several investigators, working independently, have come to the conclusion that "immunity of plants to disease is independent of any morphological characters, and that it is due to some internal and inherent character." Biffen has shown that these characters are Mendelian, and that they are inherited in Mendelian proportions. The process of breeding immune varieties of wheat must aim at combining resistant characters with other desirable characters, such as good quality grain, good straw, and good yield. This is done by (1) selecting from pure varieties those plants which are already more resistant than others under circumstances which are unfavourable to both, (2) hybridizing of varieties of known susceptibility and desirable characters with others which are known to be resistant, and then selecting the plants which show the best characters of both parents.

It will probably take some years to produce a rust-resistant variety of wheat in Egypt, but in the meantime there are a few points which should be borne in mind when cultivating wheat, and attention paid to them will very often make the difference between a good and a bad crop.

(1) *Avoid excessive watering.*—It has already been stated that excessive moisture in the soil favours the fungus. In a country like Egypt where watering is done solely by irrigation, and where the nature of the soil in different provinces differs markedly, it is impossible to lay down a hard-and-fast rule as to the number of waterings wheat should receive. The usual practice in Lower Egypt is two waterings subsequent to that given at the time of sowing. Generally speaking this is not excessive, but it is certain that where soil is a heavy loam and the water table high, such soil does not need as much watering as a lighter loam with a lower water table. Another point to be considered is the variety of wheat grown. An early ripening variety does not require so much water as a late-ripening variety.

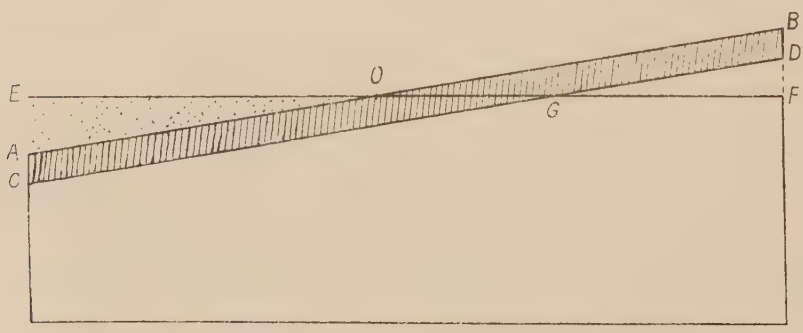
(2) *Avoid excessive nitrogenous manuring.*—An excess of nitrogenous manuring induces rank growth, causes late ripening, and predisposes the plant to disease.

It has been previously stated that only two crops of *Hindi* wheat (apart from those at Gîza) were observed to be badly attacked by black rust this year. The explanation of the severity of the attacks on these two crops will illustrate the importance of points (1) and (2).

Crop No. 1.—This crop had been heavily manured with farmyard manure, and had been watered four times. When the crop was

examined it was receiving its final watering. On examining an unwatered portion of the soil it was actually found to be quite moist about an inch below the surface.

Crop No. 2.—This crop was sown in November about ten days after the other *Hindi* crops on the same farm. All crops had received two waterings, and were the same variety of *Hindi* wheat. The main crops which were not badly attacked followed cotton, but the badly rusted crop followed *bersîm* and bare fallow. One portion of the latter crop was very badly rusted, but the other part compared fairly favourably with the better crops on the farm. Further, the very badly rusted portion was lying flat on the ground and not upstanding like the remainder. This was satisfactorily explained by the fact that *bersîm*, being a leguminous crop, increased the nitrogenous content of the soil; further, the ground had been levelled before the wheat was sown, and this, of course, necessitated the removal of the upper highly nitrogenous layer of soil from the higher to the lower portion (*see* diagram). The wheat growing on the part which was formerly the higher was much less rusted than the other portion because the top layer of the soil containing much nitrogen had been partly removed, whereas that sown on what was the low ground had received a surfeit. The wheat was lying flat on the ground because the nitrogenous content of the soil had induced too rapid growth and, being weak in consequence, could not withstand the wind.



The surface of the area under *bersîm* is represented by the line AB, and the upper layer of the soil rendered highly nitrogenous by ABCD. When the ground was levelled the soil, represented by OBF, was transferred on to AO, thus bringing the level of the whole area to EF. The result of the transfer of the soil OBF was that OEC was highly nitrogenous and, as a result, the crop grown on OE was lying on the ground and very badly rusted. The wheat on GF was upstanding and very much less rusted.

(3) *Sow as evenly as possible.*—The humidity of the air within a portion of a crop which has been heavily sown is higher than in the case of the more thinly sown portion. This increase in the humidity is suitable to the germination of the spores, and so infection spreads more rapidly.

(4) *Time of sowing.*—Late sown wheat becomes more badly rusted than early sown wheat, and if sown very late it ripens prematurely in the hot weather and so does not give as much yield per *feddân* as the early sown wheat. The best time to sow wheat in Lower Egypt is at the end of October or early in November.

THE LOOSE SMUT OF WHEAT.

The cause of this disease is a fungus called *Ustilago tritici* (Pers.) Jens. The disease is found in almost every wheat crop in Egypt, but the loss caused by it is, at present, almost negligible. It is possible, however, that the new varieties of wheat which are from time to time introduced into Egypt may be highly susceptible, in which case treatment will become necessary. This disease, like most smut diseases, affects the ears, replacing the normal grain by a mass of dark brown powder (Plate V, Fig. 3). This powder consists of myriads of tiny spherical bodies called spores (Plate VI, Fig. 1) which do not form compact bodies, but are loose (hence the name) and are easily blown about by the wind, often leaving behind nothing but the bare central stalk (rachis). Most of these spores perish after a short time, except those which fall on the flowers of the healthy plants. These spores measure less than $\frac{1}{100}$ centimetre in diameter and are covered with tiny spines. They germinate in moisture and produce a branched system of very fine threads (germ tubes) (Plate VI, Figs. 2 and 3). These germ tubes are able to pierce the stigma of the wheat flower and grow downwards through the passage left by the pollen tubes, until they reach the inside of the young grain. The young seed thus infected is not harmed by the presence of the fungus, and continues its growth and ripens like the uninfected grains. There is no means of recognizing the infected from the uninfected.

The fungus undergoes no further development until the seed is sown in the following season. As the seed germinates, so the fungus resumes its activity and grows upwards inside the plant stem, keeping just behind the growing point. Usually no signs of its presence in the plant can be seen until the ear appears, when the fungus produces the mass of brown spores in place of the normal ear. Sometimes, however (particularly in the case of Dakar wheat: *Baladi*), the diseased

plant can be recognized a considerable time before the emergence of the ear. In such cases the uppermost leaf becomes split longitudinally and bears black masses of the fungus spores.

Protective Measures.

(1) Do not use seed from a crop which has smutted ears.

(2) Grow seed plots which can be examined daily during the period of the appearance of the ear. The smutted ears should be covered closely with a cloth or paper bag, and the plant pulled out and burnt. To pull out the infected plant as it stands is the worst thing possible because by so doing the spores are scattered and fall into the flowers of the healthy plants, thus bringing about infection.

(3) The fungus can be killed inside the seed without interfering with the germinating power of the grain by treating the seed with hot water. This is done by soaking the seed in lukewarm water (20° to 30° C.) for about five hours and then transferring into a vessel containing water at exactly 54° C. in temperature for ten minutes. On no account must the water be allowed to exceed 54°·5 C. or go below 53° C., nor must the seed be left in the water at 54° C. for more than ten minutes. Water at a temperature exceeding 54°·5 C. injures the seed, and water below 53° C. does not kill the fungus.

Soaking the seed in a solution of copper sulphate of any strength is ineffective against this disease.

THE LOOSE SMUT OF BARLEY.

The fungus which causes this disease is known as *Ustilago nuda* (Jens) Kellerm et Sw. It is very closely allied to that which causes the loose smut of wheat and its life history is the same. Similar spores are blown about by the wind, and those that fall on flowers of the healthy barley plants germinate and infect the young grains (Plate VI, Fig. 4). The smutted ears appear slightly earlier than the rest of the crop.

The disease is very rarely met with in Egypt, and during a tour throughout Egypt this year only a single case of the disease was observed.

Protective Measures.

The treatment of this disease is not necessary at the present time, but should it become so in future those measures already described for the "Loose Smut of Wheat" apply equally well to it, with this slight difference: In the case of hot-water treatment only a temperature of 52° C. is allowed, because barley is not so resistant to heat as wheat, and the grain is immersed for fifteen minutes instead of ten, this longer period being necessary to kill the fungus.

CLOSED OR COVERED SMUT OF BARLEY.

The disease is caused by a fungus known as *Ustilago hordei* (Pers) Kellerm et Sw.

The crop of young barley may look perfectly healthy and yet, at the time of earing, several of the ears will be seen to have a blackened appearance (Plate V, Fig. 1). Such diseased ears can be more easily detected at the period of ripening because they show up better in the yellowing corn than when it is still green. Very often the diseased plants are stunted in growth and the diseased ears are sometimes partly enclosed by the leaf sheath.

On examination the diseased grains will be found to be composed of a black compact body enclosed by the husks. The black compact body is almost entirely composed of a mass of tiny bodies called spores. The spores are almost spherical, brown, but lighter on one side than the other, and measure about $\frac{1}{1000}$ centimetre in diameter. These spores are enclosed in the silvery husk until the barley ripens, so that infection of the flowers does not take place.

At the time of threshing the smutted ears are broken and the spores are spread amongst the sound grain, to the outside of which they adhere. When the seed is sown in the following year, the germination of the spores takes place at the same time as the germination of the seed. The spores, on germinating, produce a three-celled thread (promycelium), each of which gives rise to elliptical and colourless bodies called sporidia (Plate VI, Fig. 5). These sporidia become detached from the promycelium and give rise to a fine thread (germ tube) which is capable of piercing the tender tissue of the young barley seedling and causing infection. the fungus then produces inside the plant a system of threads (mycelium) which keeps pace with the growing plant until the time when the ears are formed. The fungus then produces a mass of spores which replaces the normal grain.

The spores are also present in the soil and, after germination, the sporidia are able to live saprophytically (*i.e.* on dead organic matter). It is very unlikely that these spores are able to live in the soil from one season to another in Egypt, where the soil is irrigated from time to time. The alternation of excessive moisture and dryness in the upper layers of the soil, coupled with a considerable variation in temperature, probably ensures the germination of the spores when the soil is moist and their death when the soil is dry and hot.

An estimate of the loss caused by this disease was made for Lower Egypt this year. Several crops were examined in each province, and in no case was the loss estimated at less than two per cent. Near Quwesna, Minufîya Province, the loss in one crop was estimated at

twenty per cent. The average loss throughout Lower Egypt was five per cent.

In addition to this direct loss to the cultivator, due to a considerable decrease in yield per *feddân*, it is understood that smutted samples of barley do not fetch a good market price, on account of their being unsuitable for brewing light ales.

Preventive Measures.

The methods of preventing this disease consist in killing the spores which are adhering to the seed coats. This can be done by disinfecting the seed by means of chemicals or by means of the hot-water treatment for seed described under loose smut.

(1) *Copper Sulphate* (*Blue Stone*).—Copper sulphate has been used in several countries as a seed disinfectant, and has been wrongly recommended in Egypt for use against the loose smut of wheat and loose smut of barley, against which it is useless. Various strengths of the solution have been recommended from time to time, ranging from one to ten per cent. Recent experiments have shown, however, that the stronger solutions injure very considerably the germinating power of the seed. A two per cent solution does not appreciably interfere with seed germination and is quite effective against smut spores. The solution is prepared by dissolving one kilogramme of copper sulphate in fifty litres of water in a wooden or earthenware vessel. The seed is spread on a clean floor and sprinkled with the solution until every grain is thoroughly wetted, the seed being repeatedly turned over during the process. The seed is then spread out to dry, and should be sown as soon as possible.

(2) *Potassium Sulphide.* Immersing the grain in a solution of one kilogramme of potassium sulphide in 100 litres of water has been used in Europe. It is not to be recommended, however, since the composition of the commercial potassium sulphide (liver of sulphur) varies in its composition and is often adulterated.

(3) *Formalin.* —A solution is made of one kilogramme of commercial formalin (*i.e.* a solution containing 37 to 40 per cent of formaldehyde) to 400 litres of water. The treatment is carried out as for copper sulphate, but when the seed is thoroughly wetted it is then covered with damp sacking (or any other suitable material) to stop the evaporation and left for four hours. At the end of the four hours the seed is allowed to dry and should be sown as soon as possible.

Of the above methods the most efficient and the least troublesome is the formalin treatment. When, however, the loose smut is also present, the hot-water treatment (already described) does for both.

THE LOOSE SMUT OF OATS.

This disease of oats appears, like the loose smut on wheat and barley, and is caused by an allied fungus called *Ustilago avenæ* (Pers.), Jens. The smut becomes apparent as soon as the ears are formed (Plate V, Fig. 2). At first the smutted grain of the newly emerged ears are enclosed by the glumes (husk), but this soon cracks and a dark brown powder (spores) is blown about by the wind, leaving only the stalks. This dispersion by the wind is not completed so quickly as in the case of loose smut of wheat and barley, but goes on until the crop is nearly ripe. Sometimes only the lower grains of the ear will be affected and those at the top only partially affected or normal. The spores, when blown by the wind, often fall into the flowers of healthy plants and eventually become wedged in between the grain and the glume ; these do not germinate immediately and infect the grain, but remain where they are until the grain is sown in the following season. Other spores adhere to the outside of the husk.

The spores are very small, oval or round, light brown, and are often lighter in colour on one side than on the other. They are covered with very fine spines and measure about $\frac{1}{120}$ centimetre in diameter. They germinate like the spores of the closed smut of barley and produce a four-celled thread (promycelium) (Plate VI, Fig. 6). Each cell of the promycelium gives rise to small outgrowths (sporidia) (Plate VI, Figs. 6 and 7). These sporidia infect the oats in the seedling stage as in covered smut of barley. The spores can retain their power of germination for over seven years and in the presence of suitable nutriment can live saprophytically for a year.

Although the spores are able to retain their vitality for a long time, the remarks referring to the spores of covered smut of barley present in the soil are applicable to this disease.

The same fungus also commonly attacks wild oats (*Avena fatua* L.) in Egypt.

Preventive Measures.

These, as in the case of closed smut of barley, consist in killing the spores which are adhering to the outside of the seed and those lodged between the grain and husk.

(1) The hot-water treatment described under loose smut of wheat, which consists in immersing the seed in water at about 48° C. for

some minutes, then transferring into a vessel at 55°.5 C. for ten minutes, is effective but very troublesome.

(2) *Copper Sulphate.*—This chemical, so much used against closed smut of barley, is not satisfactory against this disease. The solution takes a long time to reach the spores, which are wedged in between the grain and husk, and by that time it destroys the germinating power of the seed. In some countries the following method is used :—

The grain is immersed in a half per cent solution (*i.e.* one kilogramme of copper sulphate for 200 litres of water) of copper sulphate over-night, then transferred into milk of lime of six per cent strength (six kilogrammes to 100 litres of water). The milk of lime neutralizes the effect of copper sulphate and protects the delicate shoots of the seedlings. The copper carbonate which is formed on the outside of the grain also affords protection against infection from the soil.

(3) The most popular method at the present time is the formalin treatment, which was described for use against the closed smut of barley. The seed is sprinkled with a solution of formalin in water (one kilogramme of commercial formalin in 400 litres of water) until all the seed is thoroughly wetted. The heap is then covered with wet sacking for four hours to prevent evaporation, and allowed to dry. The seed should then be sowed as soon as possible.

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U.S.D. of Ag., Bur. Pl. Ind., Bul. 216.

Note.—The coloured plates are the work of Hassan Eff. Raouf, of the Entomological Section. The information concerning the dates of appearance of first and full ear and the date of ripening was obtained from Khatib Eff. of the Botanical Section.

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Plate II.

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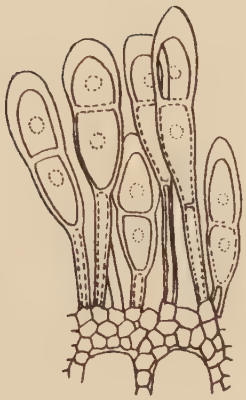

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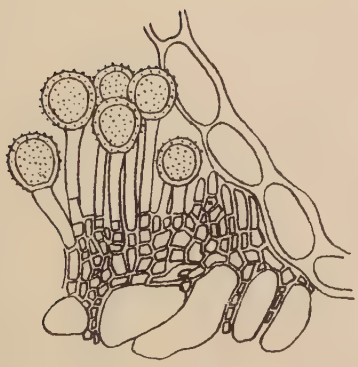

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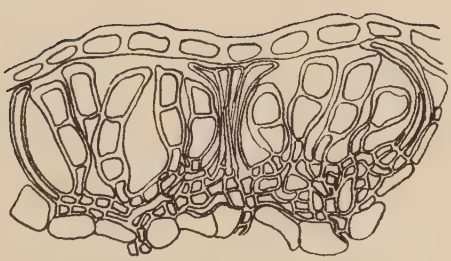

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WHEAT VARIETIES — PLOT C — LAB. GIZA 1920

PLATE III

NOTE. Degree of attack:- ·1=A few pustules observed on one or two plants only – 1= Very slight attack
2= Slight attack – 3=Medium attack – 4=Bad attack – 5=Very bad attack

Variety of Wheat	Number of days growth for appearance of first ear.	Ditto. for full ear	Ditto for Ripening	Ditto for first appearance of Orange Rust	Ditto for first appearance of Yellow Rust	Ditto for first appearance of Black Rust	Degree of attack of Orange Rust at time of ripening	Degree of attack of Yellow Rust at time of ripening	Degree of attack of Black Rust at time of ripening	Remarks
Persian (Red)	117	129	173	120	123	123	2	3	5	South African Wheats
Persian (White)	116	126	173	98	123	102	2	·1	5	
Gluyas Early	87	110	164	99	119	110	5	·1	4	
Klein Koren (Red)	87	103	154	98	108	99	4	·1	4	
Klein Koren (White)	87	103	154	96	110	99	4·5	·1	4	
Fayoum A	95	133	178	98	112	103	3	3	3	Tunisian Wheats
Magraby 45	90	128	175	98	112	102	3	3	3	
Assiut Beladi	94	105	164	114	108	118	·1	4	4	Egyptian Wheats
Beladi 31	111	123	170	108	108	123	·1	4	·1	
Beladi 42	96	105	164	118	108	118	·1	4·5	3	
Beladi 33A	105	116	168	124	108	116	·1	4·5	2	
Beladi 33	104	115	168	124	108	122	·1	4	·1	
Beladi 26	114	126	173	114	108	123	·1	5	3	
Beladi 25A	115	126	173	120	108	103	·1	4	4	
Beladi 25	105	116	167	104	108	×	·1	4	×	
Beladi 24B	105	116	167	118	105	120	·1	5	·1	
Beladi 9	116	131	173	103	108	×	·1	5	×	
Beladi 8	101	111	166	105	108	×	·1	5	×	
Indian XXV	87	103	161	95	112	101	4	·1	5	Indian Wheats
Assiut Hindi	92	110	168	98	117	101	4	4	5+	
Hindi XXII	92	102	160	98	×	101	3	×	5	
Hindi XIX H	101	111	168	98	123	101	4	·1	5+	
Hindi XVI	91	103	168	98	122	99	4	·1	5	
Hindi XI	89	101	163	98	119	101	2	1	5	
Hindi IX C	91	109	161	98	×	102	2	×	5	
Hindi VIII B	94	105	163	98	×	102	2	×	5+	
Balls	95	110	168	96	122	101	2	·1	5+	
Gibson's	87	103	166	?	122	98	2	·1	5+	
Hindi E	87	101	159	98	117	102	2	·1	5+	
Hindi D	91	109	168	98	119	101	2	·1	4	
Hindi 32	81	97	160	96	117	101	2	·1	4	
Hindi 34R.	95	109	163	94	111	102	4	·1	4·5	
Hindi 39	95	113	166	98	117	102	2	·1	4	
Hindi 40	87	103	166	98	119	102	3	·1	4	
Hindi 12	101	113	166	96	119	103	2	·1	4	
Hindi 7	87	101	163	101	122	101	2	·1	4	
Yandilla King	119	130	176	98	122	119	5	2	2	Australian Wheats
Currawa	119	134	176	98	122	119	5+	·1	2	
Nardoo	103	113	166	98	117	102	4·5	·1	4	
Marshall's 3	118	131	171	98	123	122	4	1	2	
Huguenot	113	122	171	113	×	128	1	×	4	
Thew	94	108	161	96	111	120	4	·1	4	
Firbank	81	101	161	96	111	101	5	·1	4·5	
Comeback	91	107	160	98	119	101	3	·1	4	
Sunset	56	66	141	87	111	95	5	·1	4	
Federation	85	101	161	98	×	108	4	×	2·5	
Bomen	94	113	166	94	115	119	5	·1	4	
Warren	105	115	170	98	119	108	3·5	·1	·1	
Rymer	111	126	155	98	122	122	4	·1	2·5	
Cedar	94	120	164	98	136	108	4	·1	3·5	
Bunyip	80	94	154	94	111	101	5+	·1	2·5	
Florence	77	98	158	87	111	92	4·5	·1	1	
Bobs	87	120	168	98	126	122	5+	·1	1	

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Plate VI.

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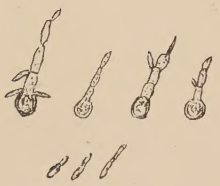

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